Interactive Areal Annotations for 3D Treemaps of Large-Scale Software Systems

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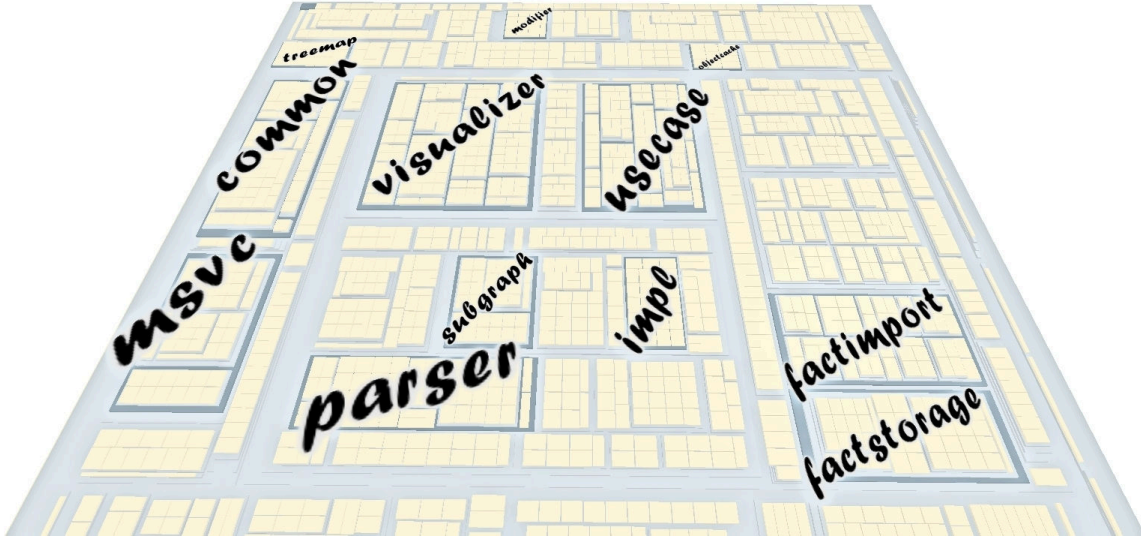
Fig. 1. Labeling interactive 3D treemaps using areal annotations provides legibility, unambiguousness and stable layouting for exploration.

Abstract—Exploration of large-scale software systems typically poses a challenge to human mind and perception. Among other approaches to this challenge, visualizing such tree-structured data using treemaps is a common solution. Especially three-dimensional treemaps enable intuitive exploration through a large-scale software system using the landscape metaphor for navigation. Annotations of treemap nodes contribute essential semantic information, e.g., class or method names. However, textual annotations in three-dimensional environments typically suffer from ambiguousness, illegibility and instability.

In this paper, we propose an interactive labeling algorithm suitable for 3D areal annotation of large-scale software systems that are visualized using three-dimensional treemaps. We demonstrate how the algorithm generates an unambiguous and stable layout with respect to legibility using 3D treemaps of a software visualization tool that visualizes the hierarchical structure of a large software system, e.g., Google Chromium.

Index Terms—labeling, annotation, virtual worlds, virtual environments, information visualization, real-time rendering.

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1 INTRODUCTION

Software visualizations deal with exploration and analysis of complex software systems for various tasks, such as fault localization, program comprehension and project management. The key challenge is to visualize large data sets contained in such software systems for purposes of exploration and analysis. One approach to visualize and explore such a software system is using a 3D treemap. Thereby, 3D virtual environments containing spatially referenced software artifacts enable intuitive navigation such as through city models. A 3D treemap represents an acyclic, directed graph, containing software artifacts as its nodes in our case. We distinguish two kinds nodes: cluster nodes (non-leaf nodes) and child nodes (leaf nodes). Since we focus on the usecase of overview exploration, cluster nodes represent the primary information source. Information about child nodes become visible not until further interaction. To identify names and roles respectively of nodes, additional information must be integrated into the 3D visualization as textual elements. We apply annotations to contribute essential,

spatially visualized information associated with these nodes. To enable an effective and efficient information flow, this association must be unambiguous (annotations clearly refer to nodes) and stable (annotation layouts are comprehensible to the user over time). In particular, labeling 3D treemaps of software structures demands for a special management of the available space. We introduce the concept of areal annotations for top-hierarchy treemap nodes. Using our algorithm, essential overview information can be visualized for further exploration and analysis of large-scale software systems.

2 RELATED WORK

The assignment of annotations to annotated objects should be as clear as possible to guarantee effectiveness and efficiency of information transfer to the user. Hence, the "nature" of the annotated object (reference object) can be considered to geometrically adapt annotations to reference object. Hence, it follows that annotations for point objects, line objects, areal objects and finally volume objects show different characteristics and require specific labeling concepts. In the following, we focus on labeling techniques for 3D environments. Maaß and Döllner [2] present an image-based labeling technique for points. Thereby, annotations are related to a 3D point. Occlusions between annotations are handled in 2D space. Annotations are added to the visualization as a 2D overlay. The association between annotation and

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point is established by an external line from the annotation center to the point.

Labeling techniques for lines such as [3] restrict potential label positions to a line, on which the label floats interactively depending on the current camera position. Labeling techniques for volumes such as [1] restrict potential label positions to a 3D hull, which represents a generalized 3D volume of the original geometry. In our approach, we restrict label positions to the top face of a node to achieve full label visibility with low computational effort.

3 CONCEPT OF AREAL ANNOTATIONS

Annotations are embedded as textual elements into the scene. Hence, we place and transform annotations as 3D objects. The computation of the transformation addresses three aspects: (1) translate annotations to the center of the cluster's top face (see 3.1). (2) align annotations to the cluster diagonale that they fit into the lower left and upper right corner of the cluster (see 3.2). (3) set up annotations if camera position moves near the ground (see 3.3).
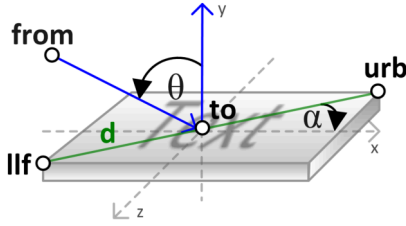
Fig. 2. Deriving the transformation using the cluster geometry and the camera properties.

3.1 Use Interpolation for Spatial Coherence

We use smooth transitions between two label placements to provide spatial coherence. We translate the label to the cluster center to ensure intuitive stable layouting and use the lower left front vertex and the upper right back vertex of the cluster bounding box to fix the label to the cluster corners. Since we deal with interactive visualization, we apply interpolation between old and new position depending on the camera activity: Labels only move to new positions after the camera is fixed for a user-defined period of time.

3.2 Align Annotations to Cluster Size

In 2D cartography, the annotation of areas is implemented by stretching the text spatially close to the area size. This method avoids that the label is associated with a single point on the area but with the area itself.

We adapted this method by scaling labels to the cluster size to provide uniqueness. Hence, we make clear that an area is annotated, e.g., in contrast to a child node on the cluster. We further align labels to the diagonale on the XZ-plane of the cluster (Figure 2). Altogether, labels are stretched along the cluster diagonale.

Mathematically, the transformation is represented by a non-uniform scaling and a rotation around the cluster normal, which conforms to the y-axis in our case (Figure 2). The scale factor is computed using the annotation size $size_a$ and the cluster size $size_c$. To determine the size, the length of the diagonale is calculated using the lower left point llf and the upper right point urb of the cluster rectangle (top face). The rotation angle α is computed by means of the dot product between diagonale vector and the lower edge vector:

$$\alpha = \arccos\left(\overrightarrow{urb - llf} \cdot \begin{pmatrix} x_{urb} \\ y_{llf} \\ z_{llf} \end{pmatrix}\right)$$

In case of short textual contents, the scaling is adjusted to avoid such large-sized labels (Figure 3). Hence, we define a maximum scale factor.

Fig. 3. Labels are scaled to cluster size to provide association of the label with the whole cluster area.

3.3 Set up Annotations for Pedestrian View

In 3D treemap visualizations we have to maintain legibility in case of orthogonal views as well as pedestrian views. We use the camera tilt angle to adjust the label transformation. Hence, labels are set upright for large angles between the camera look-to and the normal of the cluster surface (Figure 4). The tilt angle $\theta \in [0°, 90°]$ indicates the rotation angle around the x-axis: $\theta = 0°$ means the camera views from above. In this case, no further rotation is necessary. $\theta = 90°$ means the camera views from the ground at the treemaps. Hence, the annotations are fully straightened up so that they appear to stand on the treemap clusters (Figure 4). In case of $0° < \theta < 90°$, the degree of tilt is linearly interpolated.
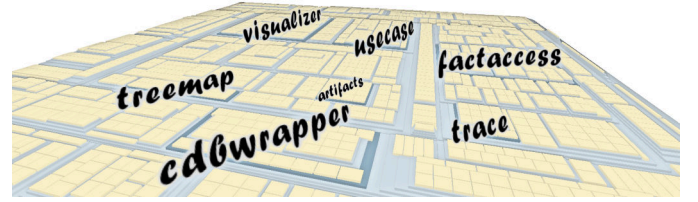
Fig. 4. The more the camera nears the ground, the more annotations are set upright.

In case of tilted views, top node surfaces of the treemap are perspectively distorted. Due to this distortion, annotations appear slightly below the node's middlepoint. We correct this displacement by applying a transformation that raises each annotation above the treemap. The height to which the annotation is raised is set to half of the text height. This translation involves that annotations are centered on the cluster that is distorted according to the perspective. In case of orthogonal views, the translation has no effects.

4 CONCLUSIONS

A 3D labeling concept is presented that visualizes essential semantic information in three-dimensional interactive treemaps. Areal annotations adjust to visible top faces of treemap nodes to provide unambiguousness, legibility and efficient space management. Since areal annotations are attached to node top faces, the user can easily follow and perceive new annotation layouts during camera movement, such as pan, zoom or rotate. We also consider availability of our labeling algorithm for individual applications. Therefore, we integrate an implementation of interactive areal annotations to a software library. Thus, we enable its usage for new applications that visualize complex structures such as hierarchies

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